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PROJECT MANAGEMENT AND THE ORGANIZATION
PART I

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THE PROJECT MANAGEMENT RESEARCH SERIES

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ABSTRACT

This report examines the organizational structure and relations to the total organization of the Apollo Program hardware research and development projects. It employs a refined model of matrix theory to relate the workings of the project groups to selected characteristics of their personnel and their tasks. This, in turn, is used to relate the project organization to a general theory of organization. The study particularly focuses on the relations between the project groups and the rest of the NASA organization. The data for the study was gathered in interviews with project managers, subsystems managers and related personnel at MSC and MSFC and Apollo Program and other NASA personnel at Headquarters.

Part I discusses organization, theory and project management theory and presents the refined model of the matrix approach to organizations. Succeeding papers in this series will discuss the application of this model to Apollo project management.

Large, complex organizations play an increasingly important role in modern society. Large organizations virtually dominate many important sectors of the American economy. Already, complex corporations are being joined into more complex conglomerates and are moving across national boundaries. Large governmental bureaucracies have been inveighed against for decades, yet many problems on the political agenda call for increasing, not decreasing, governmental effort. Suggestions for involving private enterprise in a "partnership" with government to tackle some of these problems conjure visions of even greater organizational complexities. Modern man is employed by a large, complex organization, spends his money to buy the products of similar large, complex organizations, lives in cities, states and a nation governed or administered by such large, complex organizations, has been educated, for the most part, by schools which are also large and complex, and, in general, finds his life defined by such organizations.

There have been a number of approaches to the construction and explanation of organizations. The first and foremost of these is the bureaucratic theory. It has become so imbedded in the thinking of people about organizations that bureaucracy has become a perjorative synonym for a large, inefficient, and usually governmental, organization. As organizations have become more complex, they tend to diverge from the bureaucratic model. Though other ways of describing the organization may be more informative, it is still formally structured bureaucratically.

As this development advances, some exceptions to the bureaucratic structure may be recognized as such. Project management is generally recognized as an exceptional form of organization. It is being used as the basis for the organization of more and more endeavors. As a way of organizing and as an explanation, project management is generally considered as a special case. Normal or standard operating procedures are not applicable to project management. Nothing learned from project experience can be applied to any other type of organization.

This study takes a much different point of view. It seeks to understand project management as one form among several for structuring the diverse tasks of a complex organization. It seeks to open an interchange of applications and ideas between traditional and project oriented organizations, both in theory and practice.

The first two sections present the theoretical viewpoint of this work, which is based on a form of matrix theory. Succeeding sections seek to delineate the structure of project management groups, their differences and similarities to other forms of organization, their relationships to other organizational groupings. The final sections illustrate how a new approach to organization can explain both forms of organization and their interrelationships.

SECTION I CONTEMPORARY ORGANIZATION:

BUREAUCRATIC AND NON-BUREAUCRATIC THEORY

Bureaucracy

One of the most pervasive explanations of formal organization and organization behavior is the bureaucratic ideal type developed by Max Weber and others.[1] Though there have been other approaches to the formulation of a general theory of organization, such as those of Herbert Simon and Talcott Parsons,[2] they owe much to Weber's seminal contributions. The principal outlines of Weber's ideal type are familiar to students of organization and are treated by many authors.[3] Here it is necessary to give only the broadest characterization of Weber's thought.[4]

Weber started by identifying three types of authority: charismatic; traditional; and legal. He felt that there was a general tendency

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[1]Max Weber, The Theory of Social and Economic Organization, A.M. Henderson and Talcott Parsons (trans.) and Talcott Parsons (ed.), Glencoe, Illinois: Free Press, 1947 and H.H. Gerth and C. Wright Mills (trans. and eds.), From Max Weber: Essays in Sociology, New York: Oxford University Press, 1946.

[2]Herbert A. Simon, Administrative Behavior (2nd Ed.), New York: The MacMillan Company, 1957. Talcott Parsons, Structure and Process in Modern Societies, Glencoe, Illinois: Free Press, 1960. For a discussion of the various approaches to organizations, see Amitai Etzione, Modern Organizations, Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964 and Dwight Waldo, The Study of Public Administration, Garden City, New Jersey: Doubleday, Inc., 1955.

[3]See Reinhard Bendix, Max Weber, Garden City, New York: Doubleday, Inc., 1960, as well as the previous citations.

[4]The following discussion is largely taken from Peter M. Blau and W. Richard Scott, Formal Organization: A Comparative Approach, San Francisco: Chandler Publishing Company, 1962, p. 30ff, and Victor A. Thompson, Modern Organization, New York: Alfred A. Knopf, 1965, p. 10ff.

for society to move away from the charismatic and traditional forms and toward rational, legalistic forms of organization. Weber labeled the fully developed legalistic form of organization, bureaucracy; then he described its characteristics. The first was a clear-cut division of labor, which in turn facilitated specialization and the development of expertise. This encouraged employment on the basis of technical qualifications, and training, and merit examinations and appointments. The second major characteristic of bureaucratic organization was the hierarchical arrangement of positions into superior and subordinate scales, with each step up the scale responsible to the superior for all those under it. The third characteristic was a set of formal rules and regulations which circumscribe the authority of superiors over subordinates and guide the actions of all members of the organization. Weber's fourth characteristic was the assumption of impersonality in dealing with both members and non-members or clients of the organization. The fifth characteristic was a career system, wherein employment in the organization is regarded as a full time, lifelong career. Figure 1.1 shows an organization chart based on the bureaucratic model.

Blau and Scott point out two major, and somewhat implicit, assumptions on which Weber's analysis is based. The first is that bureaucratic organizational characteristics contribute to administrative efficiency and the second is that there is no conflict between hierarchy

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[1]Blau and Scott, op. cit., pp. 34-35.

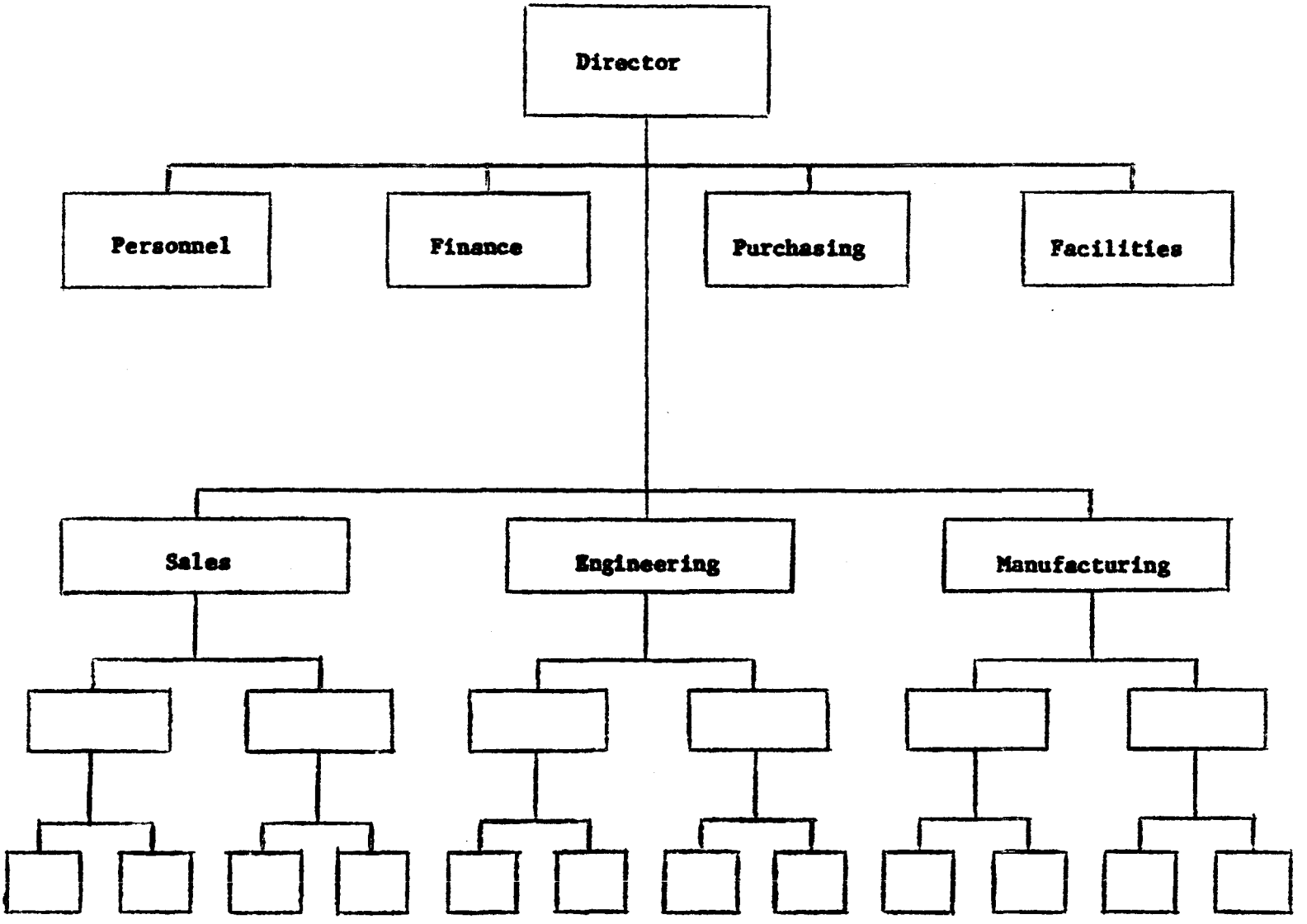

Figure 1.1 An organization chart typical of a bureaucratically structured organization.

and specialization, i.e., that the administrative organizational superordinate is also superior technically to his subordinates.

While the Weberian ideal type has been subjected to a good deal of criticism as well as amplification and modification, it retains a strong hold on students, and, even more, the "practitioners" of organization. Doubtless the most persistent of the elements of the Weberian model is the concept of hierarchy.[1] It continues in the work of later theorists such as Simon and Parsons. Of course, this is largely due to the fact that organizations are, formally at least, arranged hierarchically. But the caveat points out another reason for the persistence. Both students and actors are to some degree conditioned to see the hierarchy in organizational arrangements. Even when the informal organization has invalidated the formal hierarchy, the official explanation of how the organization is arranged is hierarchical.[2] And rarely

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[1]It is interesting to note that, in light of Weber's assumption of a movement toward rationality and bureaucracy as the ultimate development, the hierarchical concept seems to be a hang-over from the traditional types of organization as in feudalism. If, as Carl J. Friedrich suggests (in "Some Observations on Weber's Analysis of Bureaucracy", "Robert K. Merton, et. al., eds., Reader in Bureaucracy, Glencoe, Illinois: The Free Press, 1952), Weber's characterization of bureaucracy was not idealized, but based on impressions of the Prussian bureaucracy, it is easy to trace the hierarchical concept of feudalism through the Junker class, etc. Of course, the monocratic concept, the concomitant of hierarchy, can be traced to ancient times. See Matthew, Chapter 6, Verse 24.

[2]See Herbert G. Wilcox, "The Culture Trait of Hierarchy in Middle Class Children", Public Administration Review, Vol. XXVIII, No. 3, (May/June, 1968), pp. 222-235 and his "Hierarchy, Human Nature, and the Participative Panacea," Public Administrative Review, Vol. XXIX, No. 1, (January/February, 1969), pp. 53-63. Herbert A. Simon, Donald W. Smithburg and Victor A. Thompson point out that contemporary society provides "pre-entry" training in hierarchical procedures and the legitimacy of hierarchical authority, but that this has become increasingly diluted by counter pressures. (Simon, Smithburg and Thompson, Public Administration, New York: Alfred A. Knopf, 1950, pp. 192-200.)

do participants view this informal relationship as compensating for the inadequacies of the formal arrangements.

Nevertheless the hierarchical character of bureaucracy has often come under attack as being dehumanizing and indeed as a misleading concept. As William H. Read suggests, the hierarchical concept holds that the important business of an organization is conducted along the vertical lines of the hierarchy, while in practice this business is transacted across horizontal lines.[1] While Read sees some awareness of this shift among organizations, he calls for a "reappraisal of our traditional methods of achieving organizational goals."[2] Warren Bennis predicts the death of bureaucracy and attributes its ultimate demise to four fundamental causes: rapid technological and social change; growth in size of organization; complexity of modern technology; and, changing managerial behavior.[3] While the last may be a factor of the first three, it could easily have an accelerating effect on the process.[4]

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[1]William H. Read, "The Decline of the Hierarchy in Industrial Organizations," in David I. Cleland and William R. King, eds., Systems, Organizations, Analysis, Management, New York: McGraw Hill,Book Company, 1969.

[2]Ibid., p. 22.

[3]Warren G. Bennis, "The Coming Death of Bureaucracy," in Cleland and King, op. cit., p. 12.

[4]While it may have this effect, it would seem to be more generally the case that managers, seeking a rational explanation for their behavior, would cling to the bureaucratic rationale until an adequate alternative was offered. This, too, might explain the persistence of bureaucratic concepts, if succeeding concepts were useful for the study or organizations but gave no directions to the practitioners. Then organizations continued to be constructed along bureaucratic lines even though other concepts explained their actions - perhaps even better than the ones on which they were based.

The Project or Matrix Model

One area which is moving away from a strictly bureaucratic structure is the aerospace industry. Some of the factors which Bennis identifies are particularly strong in this field. This is especially true of complex and rapidly changing technology. Whole corporations have assumed totally new versions of organization that combine some elements of bureaucracy with some very non-bureaucratic arrangements. The basic organizational departure is variously called project organization, project-overlay organization, matrix organization and matrix overlay organization. As John F. Mee describes it:

> "A matrix type of organization is built around specific projects. A manager is given the authority, responsibility and accountability for the completion of the project in accordance with the time, cost, quality and quantity provisions in the project contract. The line organization develops from the project and leaves the previous line functions in a support relationship to the project line organization."[1]

As George A. Steiner and William G. Ryan point out, types of project organization vary enormously from one another, but they identify three general categories: the "pure" project organization, in which the project personnel are administratively assigned to the project, and which is similar to a new division; the "matrix" type project organization, in which the personnel working on the project are administratively

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[1] John F. Mee, "Matrix Organization" in Cleland and King, op. cit., pp. 24-25.

in the functional divisions; and the "influence" type project organization in which the project manager acts in advisory capacity to general management.[1] It is the matrix type of project organization that poses the most interesting problems for students of organization since this form departs most radically from the more usual structures of organization. Figure 1.2 gives an organization chart typical of a matrix type project organization.

John S. Baumgartner, Steiner and Ryan and David I. Cleland and William R. King have all given descriptions of project management organization.[2] There is a strong prescriptive tendency in these descriptions, though they are partially based on observations of actual practice. That is, instead of describing how project management is done, they discuss how it ought to be done. Still, these works, together with some articles, constitute a body of project management theory which can be distilled and compared to more traditional organizatinn theory.

Baumgartner's is the earliest work in this series and perhaps the most prescriptive. He states his major purpose as to "portray the major fundamental problems which project management encounters and to outline approaches in resolving them."[3] He describes project management as:

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[1]George A. Steiner and William G. Ryan, Industrial Project Management, New York: The MacMillan Company, 1968, pp. 8-9.

[2]John Stanley Baumgartner, Project Management, Homewood, Illinois: Richard D. Irwin, Inc., 1963; Steiner and Ryan, op. cit.; and David I. Cleland and William R. King, Systems Analysis and Project Management, New York: McGraw-Hill Book Company, 1968.

[3]Baumgartner, op. cit., p. 8.

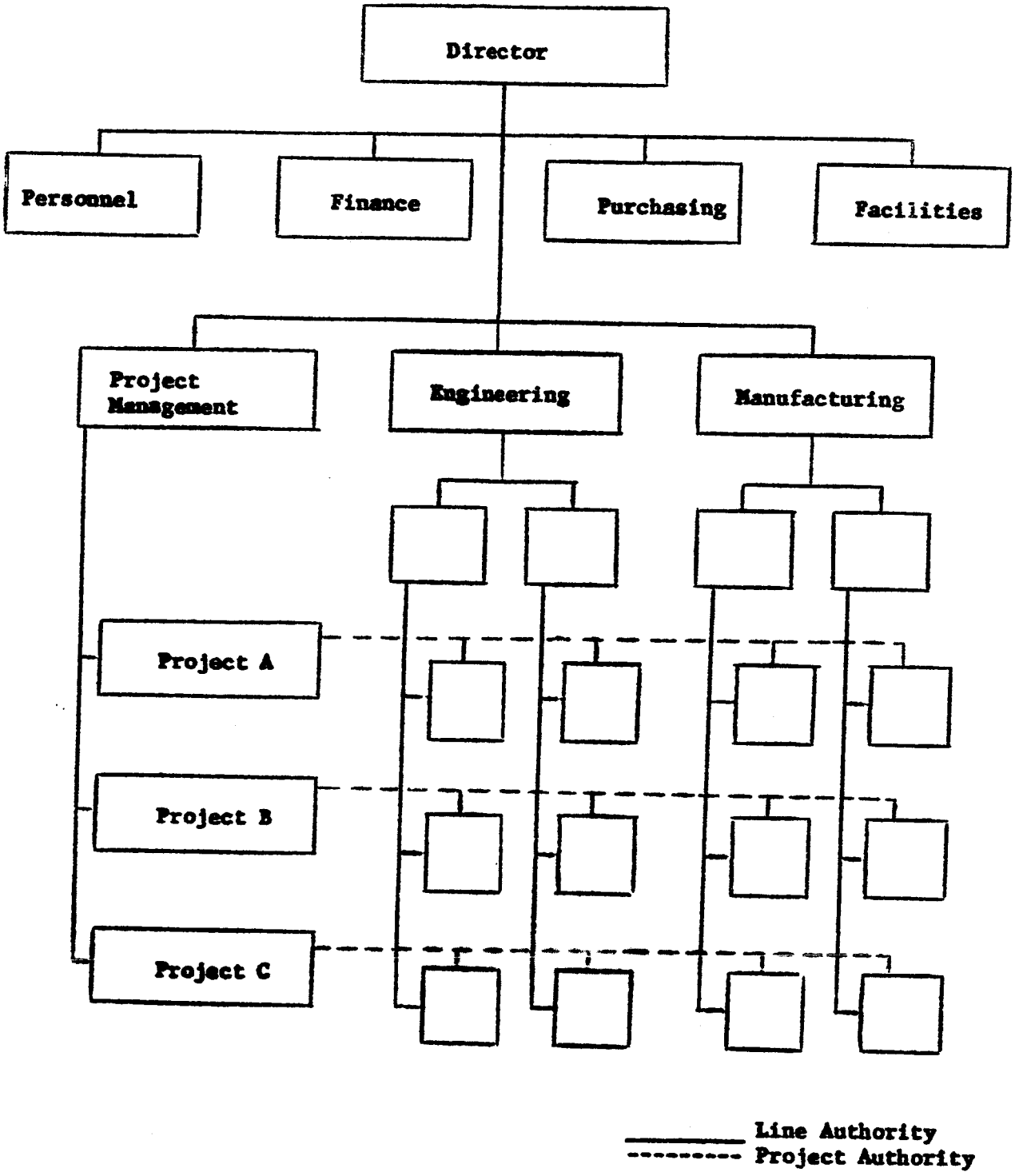

Figure 1.2 An organization chart typical of a matrix type project organization.

> "...a general management activity encompassing planning, control, supervision, and the engineering or manufacturing involved in producing the end item. It is similar to functional management and administration in that it is basically getting work done through people, with all that implies regarding objectives, incentives and communications. It differs from general administration, however, in ways which have a far-reaching effect. The project manager has very specific objectives which, when achieved, mean the end of his function. He usually has no line authority over the organizations producing the items which he must deliver. The incentives which he can offer are therefore quite different from those available to the general administrator. Communications must be very clear, prompt and comprehensive, and frequently cut across intercompany and intracompany lines and may involve two or more government agencies."[1]

Baumgartner also describes project management in a more concise formulation.

> "Project management consists of the actions involved in producing project deliverable end items on time, within the contemplated cost, with the required reliability and performance, at a profit to the contractor. The purpose of project management is to insure achievement of these objectives through the functional organizations and over their specialized interests. The project manager's role basically is one of planning, controlling and motivating the project team."[2]

Baumgartner identifies the problem areas of most concern to the project manager as project planning, project control, developing the proj-

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[1] Baumgartner, op. cit., pp. 1-2.

[2] Ibid., p. 8.

ect team, fiscal management and cost control, profit maintenance, customer relations, stopping work, extra-contractual responsibilities and self-review and evaluation.[1] Baumgartner points out that to deal with these diverse areas, the project manager requires a versatile background in administration, but that his primary background is usually in the project's main field of activity, in order to communicate with the people working on the project. As for skills, Baumgartner indicates that proficiency or understanding of budgeting, scheduling, planning, getting things done through people, marketing, contracting, control and the technology involved is required.[2] Baumgartner characterized the project manager's authority as "none, other than what the project manager can acquire by his own devices."[3]

He added:

> "Sometime in the future, when it is more generally recognized that the project management function is here to stay, the relationship between the project manager's horizontal organization and the vertical functional organizations will be more thoroughly scrutinized and the extent of the project manager's authority defined. Until this is done, however, the PM will be limping along on some kind of an understanding and a smile as the main basis for getting functional areas' cooperation."[4]

Baumgartner's description of project management can be reduced to five major characteristics. Project management entails:

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[1] Baumgartner, op. cit., pp. 9-11.

[2] Ibid., pp. 11-12.

[3] Ibid., p. 75.

[4] Ibid., pp. 75-76.

A. general management authority

B. production of an "end item"

C. limited and specific objectives in terms of time, cost and performance

D. little or no line authority

E. an emphasis on planning, control and motivation.

Steiner and Ryan's identification of three basic types of project management has been referred to above. They identify project management by the major characteristics of the project: "production of an identifiable end item; participation in the project by organizations outside the project manager's direct line control; the complex involvement of many people, processes, and skills; the presence of important technical uncertainties; and the existence of a fixed terminal date."[1]

From their interview and other data, Steiner and Ryan develop a "model of managerial philosophies, principles, and practices which were found to exist rather uniformly among successful project managers who had more than the usual amount of authority delegated from Govern-

[1] Steiner and Ryan, op. cit., pp. 18-19. It must be noted here that true to their title, Steiner and Ryan are concerned with industrial project managers and specifically disclaim the application of the "managerial model" they developed to government or customer project offices. However, the "model" states in part, "the size of the customer's office should be held small, or relationships between the customer's program office and the project manager's staff kept to a minimum or both." (p.35) The thrust of their argument is that industrial project managers should be free of "governmental interference," and that those that have been thus free have been more successful. The bootless attempt to settle questions of governmental policy on the basis of managerial efficiency weakens the disclaimer and it seems best to examine every possible source that might aid the understanding. Accordingly, a discussion of Steiner and Ryan's "model" is included in this attempt to understand project management within a governmental agency.

ment managers."[1] This "model" consists of the various rules, guides or truths that their respondents claimed were significant. Since these are mostly concerned with managerial style, only the dominant themes which have some utility or unique application to project management will be discussed here.

The "principles" collected by Steiner and Ryan are grouped under some seven headings, leadership of staff, authority, staffing, planning and control, engineering, customer relations and the contract. Of leadership, Steiner and Ryan conclude that the project manager should be "a leader of men in the highest sense of the term."[2] Since authority lies at the heart of their thesis, it is understandable that Steiner and Ryan devote a great deal of attention to the subject.

> "The project manager should have broad authority over all elements of the project. His authority should be sufficient to permit him to engage all necessary managerial and technical actions required to complete the project successfully. He should have appropriate authority in design and in the making of technical decisions in development. He should be able to control funds, schedules, and quality of product. If subcontractors are used, he should have maximum authority in their selection."[3]

Steiner and Ryan quickly qualify this broad authority by noting that no project manager can have complete authority, and

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[1] Steiner and Ryan, op. cit. , p. 68.

[2] Ibid., p. 21.

[3] Ibid., p. 24.

that the exact amount "varies from project to project, project manager to project manager, over time within the same project, and on the basis of a number of other variables."[1] Other principles listed under authority include: "Keep all interfacing as simple as possible;"[2] "The project manager must earn the respect and gain authority over elements of the program which are not under his direct formal authority;"[3] "The project manager should have maximum control over budget, extending through the functional organization;"[4] and "The project manager has and accepts final authority in major engineering matters."[5]

As for staffing, Steiner and Ryan declare "The project manager should hold the size of his central project staff over which he exercises direct control to about ten people, if possible, but no more than thirty."[6] In this section they put forth the "principle" referred to above, that the customer's office should be kept small or at arm's length. They also hold that "The project manager must try to assure the continuity of his project team, but be conscious of the need for a different capability mix as the project proceeds."[7] And that "Pay of personnel must be based upon performance and not the number of people supervised."[8]

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[1]Steiner and Ryan, op. cit., p. 25.

[2]Ibid., p. 29.

[3]Ibid., p. 30.

[4]Ibid., p. 31.

[5]Ibid., p. 33.

[6]Ibid., p. 33.

[7]Ibid., p. 36.

[8]Ibid., p. 37.

On planning and control, the authors suggest "The project manager should verify requirements and participate in the design of the project."[1] "The project manager should be abreast of developments in the critical areas of his program and formulate methods to anticipate problems."[2] Steiner and Ryan discuss a number of methods or techniques used in controlling projects. These include scheduled staff meetings, PERT/Time, PERT/Cost, and other scheduling tools, reporting, which should be kept to a minimum yet cover everything required, quality control, cost control, subcontracting and control of funds, which is particularly important to a manager in a matrix organization.[3]

On engineering, Steiner and Ryan state "The project manager should be his own chief engineer and be willing to trust his own judgment in making decisions with a high technical content."[4] And yet, "The project manager must not become embroiled in all technical matters."[5] Customer relations must be based on mutual trust and close cooperation and liason according to Steiner and Ryan,[6] and both contractor and customer should be willing to make prompt decisions[7] And fin-

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[1] Steiner and Ryan, op. cit., p. 37.

[2] Ibid., p. 43.

[3] Ibid., pp. 43-58.

[4] Ibid., p. 58.

[5] Ibid., p. 60.

[6] Ibid., p. 64

[7] Ibid., p. 67

ally, the contract involved, according to Steiner and Ryan, should give a clear statement of the work to be done and contain incentives.[1]

To be useful for present purposes, the Steiner and Ryan description needs to be reduced to a somewhat more concise statement of their position. It must be said that their approach is rather simplistic. Steiner and Ryan do not advance any theoretical view of project management, nor do they describe actual practice in adequate detail to make the description useful. While some of this may be due to security and other Department of Defense restrictions, it is more a result of a simplistic approach and an overemphasis on managerial style. As a result, the following abridged statement of their main points entails almost no distortion of their thought.

To Steiner and Ryan, project management involves:

A. production of an end item;

B. large size;

C. CC. technical risks;

D. participation of entities outside direct control of project manager.

The project manager:

A. is technically competent;

B. has as much authority as possible;

C. represents and applies general management;

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[1]Steiner and Ryan, op. cit., p. 68.

D. keeps his staff small;

E. seeks to earn respect and gain more authority;

F. participates in planning and control;

G. seeks close cooperation and mutual trust.

Again, it must be pointed out that Steiner and Ryan feel that all this is inapplicable to the government customer's project office. It seems that the reason for this is fairly clear. Steiner and Ryan are concerned with the authority of the project manager. From the nature of the beast, the project manager's authority is incomplete, unclear, and variable. The project managers that Steiner and Ryan interviewed all felt a need for or a desirability for more authority. The only way to achieve this without doing violence to the existing oranizational patterns or doing away with project management entirely is to reduce the customer's role and enlarge the industrial project manager's role. Thus, an adequately staffed, adequately informed customer program office would only duplicate work, ask troublesome questions, propose more changes, and perhaps decide to cancel the project. Rather than adapt to working with a technically competent and informed customer, Steiner and Ryan's project manager would seek to keep the customer incompetent and uninformed.

Steiner and Ryan point out that the customers involved are not content with this type of relationship and are seeking to elicit better information from and are tightening the controls on industrial project managers.[1] And they recognize that the reasons and motives for the

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[1]Steiner and Ryan, op. cit., p. 69 ff.

trend are laudatory and indeed incumbent upon the government customers. Yet they maintain that the trend is running counter to the experience and practices of the successful managers they interviewed. In this light, it is clear that the assertion that their work is not applicable to customer project offices means only that they did not examine this aspect of project management and think that customer project offices should not be organized this way. Thus, the restrictions on the application of their ideas to customer project offices are prescriptive rather than theoretical.

Cleland and King have presented another view of project management, based upon a more systematic approach than that set out in the works described above.[1] After an extensive discussion of systems analysis, these authors examine traditional management theory and its applications to contemporary organizations. They conclude that there is some doubt about the universal application of traditional theory.

> "For some time is has been realized that the flow of work and the use of authority have significant lateral and horizontal relations. The role of the superior has changed from that of a powerful executive who controls the people to that of a manager who provides an environment in which his people can work with the many different groups in the total environment. Bureaucratic theory considers that the main problems of management exist only within boundaries of the parent organization. Little attention has been given to the manager's effect on contracts and negotiations outside the company."[2]

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[1] David I. Cleland and William R. King, Systems Analysis and Project Management, New York: McGraw-Hill Book Company, 1968.

[2] Cleland and King, Systems Analysis and Project Management, op. cit., pp. 148-149.

The impact of their systematic outlook is apparent in the preceeding quotation. This point of view led Cleland and King to discern that the institution of project management has entailed and engendered a wholly new pattern of organizational arrangements along the lines of working relationships rather than the traditional alignments. There are four major elements in the new pattern.

> "FUNCTIONAL SUPPORT - Functional support consists of facilitative technology provided for the company by various groups. In a manufacturing organization, this element would be supplied by three groups, designated 'production', 'marketing', and 'finance'. Functional support is provided for all projects in the organization as well as for the advancement of the state of the art in a particular discipline.
>
> "PROJECT MANAGEMENT - Project management is carried out by a set of managers acting as unifying agents for particular projects in respect to the current resources of time, funds, materials, people, and technology. The project managers act as focal points for their project activities through a unique organization superimposed on the traditional functional organization structure. The project managers are, in effect, the general managers of the company for their particular projects. They actively participate in planning, organizing, and controlling those major organizational and extra-organizational activities involved.
>
> "ROUTINE ADMINISTRATION - Routine administration involves the accommodating services provided for mission related activities. These services include the centralized activities required to keep score on the business as a whole, as well as the routine administration and accounting of funds, people, materials and ideas. Examples are the personnel function, repetitive business data processing, and recurring logistic support.
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> "RESEARCH AND DEVELOPMENT (LONG-RANGE PLANNING) - Research and development activities are those concerned with advancing the strategic state of the art in the functional areas and with developing a system of plans for the company's future. This group is less concerned with accomplishing current work than with obtaining future work and finding new uses for existing resources; consequently, their work is more conceptual and abstract than that of other elements.[1]

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[1]Cleland and King, Systems Analysis..., op. cit., pp. 164-165. Emphasis in the original.

Cleland and King describe project management in more detail as requiring horizontal and diagonal relationships.

> "In such an organization, managers and technicians deal horizontally with peers and associates at different levels in the same organization and with outside organizations. To follow the "chain of command" would be unwieldy, time consuming, and costly and would disrupt and delay the work. Horizontal and vertical contacts grow out of the necessity to get the job done; they are seldom charted and yet they are necessary to smooth a flow of work in the organization. These relationships have been called the "informal organization", but this is a misnomer. There may be little informality; the standards of performance may be just as stringent as those in the formal (hierarchical) structure. In many cases, these relationships have sufficient strength and permanence to become de facto the modus operandi of the organization."[1]

In comparing the viewpoints of project and functional managers, Cleland and King find the singular characteristic of the project manager is that he is responsible for and needs the cooperation of people and organizations outside of his direct control.[2] They also note that the project manager, as a focal point for the project, "becomes a source of integrated information... and an interaction point for coordinating the diverse organizational and extra-organizational activities involved."[3]

One of the things that traditional management practices, and particularly the hierarchical chain of command, did was to avoid internal conflict. Project management, by contrast, sets up conditions for a con-

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[1] Cleland and King, Systems Analysis..., op. cit., p. 151.

[2] Ibid., p. 152.

[3] Ibid., p. 165.

tinuing conflict between project and functional units. Cleland and King see this "purposeful conflict" as quite useful to an organization. Top level executives:

> "depend on a 'purposeful conflict' between project managers, on the one hand, and functional managers, on the other, as a means of evaluating relative trade offs for the time, cost, and technical parameters of a particular project, with the line and staff groups becoming very much involved. The chief executive expects his project and functional managers to resolve daily operating problems among themselves and to bring only major unresolved question (sic) to him. Management by exception is the objective."[1]

Cleland and King find that a project manager's authority or influence is based on his own professional reputation and his function and how he performs it.

> "The project manager's authority is neither all de jure (having specific legal foundation) nor all de facto (actual influence exercised and accepted in the environment). Rather, his authority is a combination of de jure and de facto elements in the total project environment. Taken in this context, the project manager's authority has no organizational or functional constraints, but rather diffuses from his office throughout and beyond the organization, seeking out the things and the people it wishes and needs to influence and control."[2]

> "The project manager is in a focal position in the project endeavors, and this focal position gives him the opportunity to control the flow of information and to have superior knowledge

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[1]Cleland and King, Systems Analysis..., op. cit., p. 165.

[2]Ibid., p. 229.

> of the project. The scope of power and control exercised by the project manager may be virtually independent of his legal authority."[1]

It must be noted here that Cleland and King's presentation on project management is one of the most sophisticated and interesting of those presently available. There is considerable detail to their treatment of the subject, but only the major outlines of that treatment are discussed here. Perhaps the most significant part of their treatment is the recognition that project management entails a new pattern of organizational structure and their discussion of the major elements of the structure. Still, Cleland and King are forced to treat project management as a special case, applicable only when certain criteria are met.[2]

The picture of project management that emerges from the works of Baumgartner, Steiner and Ryan and Cleland and King is a picture of an organizational adaptation to peculiar or special conditions. Project management is a technique to apply general management authority to the production of an end item with limited and specific objectives in terms of time, cost and performance. Project management entails little or no direct like authority and emphasizes planning, control, and motivation. But project management has some consequences for the organization which practices it. These are mainly the requirement of horizontal and diagonal lines of communication, direction and work flow; and

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[1]Cleland and King, Systems Analysis..., op. cit., p. 233.

[2]Ibid., pp. 154 ff.

the institution of built in or "purposeful" conflict.

The "Matrix" Approach

Baumgartner, Steiner and Ryan, and Cleland and King have all taken a restrictive view of project management and discuss it almost entirely in regard to hardware research and development. This restriction causes them to assume that project management is a special case, an adaptation to problems not encountered elsewhere. Such an assumption is not lodged in any theoretical necessity. Indeed, the traditional, bureaucratically structured organization has demonstrated deficiencies in many fields other than research and development.

In this situation, it would seem desirable to tie project management in with a more general theory of organization which might point out or highlight alternative approaches to the organization of efforts in other fields. This would require a much more theoretically sophisticated approach than those discussed. Fremont A. Shull, Jr. has presented the beginnings of such an attempt.

Shull takes a general systems viewpoint, as advanced by Cleland and King, and also recognizes a new pattern of arrangements. Shull analyzes organizations in terms of an administrative system, a functional system and working units or task units.[1] This can be compared to Cleland and King's combination of functional support, project management, routine administration and research and development. Project

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[1]Fremont A. Shull, Jr., "Dimensions of Matrix Organization: Cellular Structures and Control Systems," to be published in Shull, Andre L. Delbecq and Larry Cummings, Organization Decision Making, New York: McGraw-Hill Book Company, 1970, p. 9.

management can be equated to the working groups, while the administrative system does both the routine administration and the long range planning which is the major activity under Cleland and King's research and development category. Shull's propositions revolve around the working unit or task unit, which he describes at some length.

> "First, variance in task units does not relate to functional specialization in the traditional sense. The concern is with organizational units in contemporary organizations which may be seen as relatives of the 'task force'. These work units are problem (mission) rather than functionally (discipline) oriented and are different from traditional committees. This stems from the fact that such units are perceived as integral parts of structure rather than organizational overlays -- as with committees. Second, they differ from profit centers in that they may be budgeted less conventionally, i.e., output measures may be unrelated to fiscal periods and joint costing plays a proportionately unimportant role; multiple and independent accounting schedules are necessary for managerial control in the modern complex organization.
>
> "Our major propisition at this point is the plurality and differential nature of task (programmatic) units within complex organizations. The issue is not to dichotomize between functional and programmatic units but rather to scale the units themselves."[1]

Shull begins by differentiating task units on the basis of their relative autonomy or dependency in the total organization. A given or-

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[1]Shull, op. cit., pp. 10-11.

ganization could have a variety of task units either distributed along or clustered about one point of a continuum.[1] The task units are also differentiated on the basis of the technology of the unit and on the basis of the nature of the personnel of the unit.[2]

Shull uses the latter two as continua on a matrix and identifies four nodal types of organizational strategies, the routine strategy, the engineered strategy, the craft strategy and the hueristic strategy. Shull notes that they would rank in that order on a continuum from dependent to autonomous.[3] Figure 1.3 gives Shull's illustration of this matrix.

The routine strategy is used when technical/provincial personnel are engaged in similar/repetitive tasks, while the engineered strategy is applied when specialist/provincial personnel are engaged in unique/non-repetitive tasks. Professional/cosmopolitan personnel doing similar/repetitive work would be organized according to the craft strategy while creative/cosmopolitan personnel engaged in unique/non-repetitive activity would be organized along the lines of the hueristic strategy.

Shull is concerned with operating task groups, and lumps all non-operating task groups into the administrative system of the organization. He describes, partially from the study of project and task-force groups, the characteristics of the task-group and the relation-

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[1]Shull, op. cit., p. 12.

[2]Ibid., p. 13-14.

[3]Ibid., p. 15.

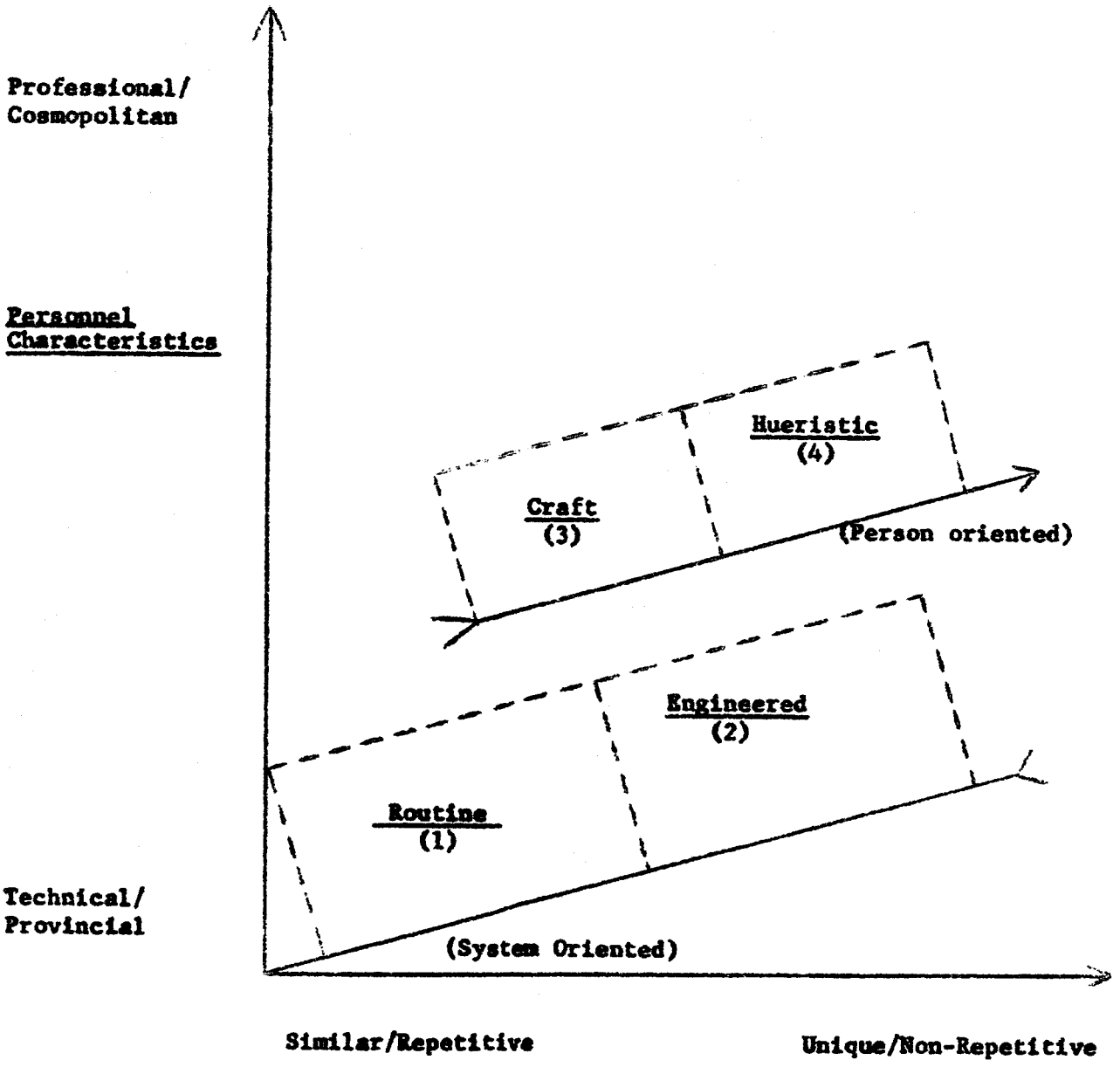

Figure 1.3 Shull's Alternative Task Unit Structures

Source: Shull, op. cit., figure 4.

ship between the task unit and the administrative system of the organization. In doing so, Shull emphasizes that these organizational designs are nodal "in the sense that, as one moves along the two continua, the increase in task variability and/or personnel competence results in the emergence of an organizational strategy for operating task units which is different in some significant way from other points on the continuum."[1] Shull also notes that the model he presents assumes "some congruence between the competence or operating personnel and task complexity..."[2]

Shull describes the engineered strategy as follows:

"Group Structure:

Specialists with designated project leader

Group Process:

Specialists with project leader jointly develop programs
a. specifying quantity and quality objectives
b. critical time-path control points
c. periodic review of program modifications

Coordination achieved by centralized communication and authority in project leader with feedback to the individual group members

Correction achieved by:
a. task assistance from leader
b. remedial effort by specialist
c. change in resource allocation of program

Group Roles:

Interdependent planning by leader and specialists
Independent instrumental implementation by specialists
Coordination by project leader

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[1] Shull, op. cit., p. 17.

[2] Ibid., p. 17.

Group Style:

Relatively high stress achieved by quantity and quality specifications agreed upon in joint consultation at major planning phases

Group Norms:

Individual responsibility of specialists
Shared responsibility and group loyalty through agreed upon program bench-marks
Economy and Efficiency"[1]

The characteristics of the administrative structure in relation to a task unit organized along the lines of the engineered strategy are given as follows:

"Planning:

Ends specified by administrative system
Resources specified through joint negotiations between engineering group and administrative system
Process largely determined by the engineering specialists and group leader

Control:

Achieved by specifications of critical control points
Input and output control specified by the program in terms of financial parameters carefully defined by the administrative system
Process controls largely lodged within the Engineeringg system
Feedback concerning input, output and process transmitted to both Engineering group and administrative system

Rewards:

Performance evaluation on resource-utilization and output rests in Administrative system
Process evaluation rests with project leader in Engineering system

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[1]Shull, op. cit. , figure 7.

Re-enforcement of loyalty to both aggregate organization and engineering group

Boundary Negotiations:

Financial parameters in terms of resources and output negotiated between administrative and Engineering systems, with the former emphasizing resource parameters, and the latter emphasizing output-feasibility

Once program is crystallized, renegotiations must be legitimated by Engineering task-group on the basis of process requirements."[1]

Shull also discusses control of the task unit in some detail, and notes that the type and specifity of administrative controls also varies according to the personnel/task characteristics of the task unit.[2]

Shull's model is presented as being less restrictive than bureaucracy because it encompasses bureaucracy as a "sub-class of the rational design which structures the variegated matrix of task units in complex organizations."[3] He also asserts that the matrix approach describes the realities of modern organizations and is more organic while bureaucracy is mechanistic. The matrix approach and the taxonomy of organization strategies are seen by Shull as "a central step in the construction of a revised theory of organization, away from bureaucracy."[4]

While Shull's work is a preliminary explanation that should be welcomed for the new insights it may provide, such weaknesses as it

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[1]Shull, op. cit., figure 8.

[2]Ibid., p. 39 ff.

[3]Ibid., p. 47.

[4]Ibid., p. 48.

may have cannot be ignored. The first problem is the question whether Shull's matrix is theoretical, descriptive, or both. Of course, Shull points out that the work is partially based on a study of project and task-force groups[1] which resolves the general question, but does not settle the question for the specific propositions on which his model is based. That is, of course, a small matter, since propositions reached by generalizing from empirical observation are just as theoretically valid as those deduced from the model itself. Still, it would be of some help to know which are which since a model may well explain what it does not require.

Shull's matrix suffers from a number of problems that range from small inconsistencies to major contradictions. For instance, his matrix is not really a two by two, four-celled matrix, but at least a four by two, eight-celled matrix, half of which he ignores. That is, on the personnel axis the progression is technician/provincial, specialist/provincial, professional/cosmopolitan and creative/cosmopolitan.

To some extent, Shull seems to have run across the problem of the differences between task specialization and personnel specialization as expounded by Victor Thompson.[2] While this may be only a factor of Shull's eliminating a fuller discussion of the variables in a compressed presentation of the matrix approach, his discussion of the

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[1]Shull, op. cit., p. 15.

[2]Victor A. Thompson, Modern Organization, op. cit.

technician as being indoctrinated to a "solution" program[1] could apply equally well to a skilled, semi-skilled or even an unskilled worker on an assembly line. Yet Shull states that his personnel characteristic continuum runs from skilled to professional.[2]

While there is less difficulty with the provincial/cosmopolitan dimension, Shull notes that some researchers have found that localism and cosmopolitanism are independent dimensions.[3] What Shull appears to be doing in continuing to use the provincial/cosmopolitan dimension is to substitute provincial, or sometimes local, for less cosmopolitan. Still, because he is not explicit, one cannot be quite sure that this is the case.

In introducing his taxonomy of complex organizations, Shull mentions three variables as crucial to the organizational dynamic; the nature of the technology, the personality and competence of the personnel and "certain institutional and/or historical circumstances.."[4] Shull points out that "Since this variable is dependent on situational and sub-cultural factors quite independent of organizational theory per se, our basic model incorporates only the first two variables..."[5] This is well and good. However, in discussing the model Shull equates any movement away from the nodal strategies with a shift in one or both

[1]Shull, op. cit., figure 5.

[2]Ibid., p. 14.

[3]Ibid., Shull refers to F. Baker, L. Goldberg and A. Rubenstein, "Local-Cosmopolitan: Undimensional or Multidimensional?", American Journal of Sociology, Vol. 70 (1964) and Alan C. Filley and Andrew J. Grimes, "The Bases of Power in Decision Processes", Academy of Management Proceedings, December, 1967, pp. 133-160.

[4]Ibid., p. 12.

[5]Ibid., p. 13.

of the two variables used in the model.[1] While such treatment may be acceptable in terms of model building, it does not seem to be of much use in applying the model to explain contemporary organizations. Since the model cannot specify the interaction between the third variable and the first two, it leaves open the possibility that the third variable could move a given task unit away from an appropriate nodal pattern without any change in the first two variables.

Shull's treatment of the third variable is similar to his assumption of co-variance between the first two variables, which allows him to ignore half of the cells in his matrix as was referred to above. Shull's model assumes:

> "some congruence between the competence of operating personnel and task complexity; that is, the model assumes that an increase in task complexity normally results in the organization recruiting more highly trained or professional personnel as well as personnel with differentiated skills and interests. We assume a correlation between the two variables. If they are not co-variant, perceptions of the technological base of the organization varies by cellular position in Matrix."[2]

In essence, this assumption collapses Shull's matrix into one dimension, for if the two basic variables are co-variant, they can be viewed as parallel continua along the same dimension. The same could be said of autonomy, control specificity, control forms, and the other

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[1] Shull, op. cit., p. 17, p. 20, et. passim.

[2] Ibid., p. 17

variables which Shull discusses. Of course, this places a large number of continua along one line, which would make it somewhat difficult to diagram and discuss. It also makes quite a number of organizational variables dependent on the two key variables of task complexity and personnel competence (together with the third crucial variable, the effect of which is unaccounted for in the model).

Finally, Shull's work is primarily concerned with "programmatic" task units which are problem/mission oriented rather than functionally/discipline oriented.[1] Yet Shull recognizes that "administrative, functional, control, service, research, and planning units do manifest structural variation consistent with the four (nodal) strategies."[2] This recognition broadens the matrix approach into at least a potential general systematic theory of organizations. While Shull recognizes this possibility, his work so concentrates on the project groups as to cause the matrix to conform to their characteristics rather than to simply explain them.

To say all this, however, does not mean that one must reject the matrix approach in its entirety. The potential insights that this approach can provide are too great and the deficiencies of the matrix approach are small in comparison to the limitations of the bureaucratic approach to organization. Accordingly it would seem that a restatement or reconstruction of the matrix approach could be used to explain the

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[1]Shull, op. cit., pp. 10-11.

[2]Ibid., p. 15.

structure of several working units in a complex organization in order to generate empirical data that might confirm, modify or reject the basic propositions of the matrix approach. The balance of the present work will be an attempt to apply a reformulated matrix approach to hardware research and development projects in the Apollo Program of the National Aeronautics and Space Administration. Section II will develop the restatement of the matrix approach, while succeeding sections will apply that approach to NASA/Apollo project management. The concluding section will summarize the implications of this application and delineate areas of further theoretical construction and empirical research.

Section II: A Reformulation of the Matrix Approach to Complex Organizations

The basic propositions of Shull's approach seem to be a valid beginning point for a reformulation of the matrix approach. The breakdown of a large, complex organization into a number of working or task units is useful both as an administrative and a theoretical approach. That such task units may be differentiated can be accepted, at the very least, as a working hypothesis. The variables which explain this differentiation are proposed on the basis of findings in the literature on organizations. These are: first, the relation between the ends and the technology of the task unit; second, the norms, aspirations and expertise of the unit's personnel; and third, certain institutional and/or historical circumstances. Shull points out that the third variable would include:

1. The makeup of the personnel system, in terms of dominance by administrators, professionals or craftsmen, unskilled workers, etc.

2. The stage of organizational growth and purpose of establishing task groups, e.g., the need for venture management.

3. Organizational norms relating the administrative system with the project groups, e.g., medical norms which place the physician in a revered position *vis-a-vis* the hospital administrator in routine services.[1]

While Shull holds that the third variable is dependent on situational and sub-cultural factors, as was pointed out above, it does not seem to be necessary to leave it out of consideration entirely.

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[1]Shull, *op. cit.*, pp. 12-13.

Shull presents the first variable in terms of the characteristics of the decision processes in a continuum from programmed to huertistic and of the processing system in a continuum from similar/repetitive to novel/unique. The second variable, personnel characteristics, is presented in terms of a continuum from skilled to professional and includes the degree of risk adversion and tolerance for ambiguity, characteristics of conceptual training and cosmopolitanism.[1]

However, there seems to be a great deal lost when these continua are developed. On the task complexity dimension, the repetitive/similar/programmed-novel/unique/hueristic dichotomy does not adequately express the rich variety of task complexity to be found in contemporary organizations. Unfortunately, in this area adequately expressive terminology is difficult to find, especially when one confronts the novel/unique/hueristic pole of the continuum. To design engineers charged with creative tasks, as with artists, novelists and other creative people, novelty is routine. If something were totally new it would be totally incomprehensible. Yet it is clear that the routines of the creative person are much more novel and unique than the routines of even a skilled worker.

It is the personnel characteristics continuum that yields the four gradations identified by Shull, as was pointed out earlier. These move from technician/provincial, to specialist/provincial, to profes-

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[1]Shull, op. cit., pp. 13-14.

sional/cosmopolitan. While this breakdown is more expressive of the diversity of contemporary organizations, it is somewhat more open to confusion because of the task-personnel specialization question. This is especially true when the question of bureaucracy is considered, for bureaucracy promotes and thrives on task specialization, while it has a great deal of difficulty in accomodating to the specialized person, that is, one who has mastered a number of complex, interrelated techniques or bodies of knowledge.[1] Although one might infer from Shull's terminology that this dimension is mostly concerned with increasing personnel specialization and omits task specialization entirely, this is not explicitly stated.

This brings out the question of creativity on this continuum, for if one is to say that the continuum expresses, among other variables, increasing personnel specialization, how can creativity be justified as the highly specialized pole or near it? However, the conflict is more apparent than real, for creativity can be viewed as the internalization of programs which enable the creative person to perceive, express and construct new programs and new interrelationships between existing programs. Thus creativity requires a highly specialized person in this sense.

The problem of congruence or co-variance between the two principal dimensions of the matrix can best be stated as a tendency toward covariance which may be moderated or modified by the action of the third

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[1]This treatment follows that of Victor A. Thompson, op. cit.

variable. The assumption of simple co-variance, or even a strong, unmoderated tendency toward it puts one in the position of saying that whatever is, is right. Yet it is fairly obvious that some organizations are more "right" by any criteria than others.

Once the assumption of co-variance is explicitly denied, we have a much more complex matrix to work with. There are now some eight combinations which can be identified. These would include, in addition to those identified by Shull, the technical/provincial-novel/unique combination, the specialist/provincial-repetitive/similar combination, the professional/cosmopolitan-novel/unique combination, and the creative/cosmopolitan-similar/repetitive combination.

Some of these combinations of task complexity and personnel characteristics seem to be highly unusual and of dubious utility while others seem to be acceptable and workable, if not optimum. The nodal designs or strategies identified by Shull are based on the accumulated theory and research in the field, and appear to be relatively familiar. In addition, with the assumption of a tendency toward co-variance or congruence, one must assume a tendency to move from these newly identified designs or strategies toward the nodal positions described by Shull. Accordingly, these combinations will be designated as subdominant, while the nodal strategies identified by Shull will be designated the dominant strategies.

Here it must be recalled that the dimensions of the matrix are continua, and although positions are identified on these continua, there are intermediate positions which remain unidentified. Any actual working

unit may fall, on one or the other or both of the dimensions, outside of the identified positions to a greater or lesser degree. But, in most cases, the dominant position which is closest to the working unit's position will serve as a point of departure for examining the actual structure and organizational relationships of the working unit. In a similar manner, a working unit which falls in a sub-dominant position can be explained in terms of the degree to which it is comparable to and contrasting with the appropriate dominant position or strategy. This approach makes it unnecessary to generate a welter of detailed organizing strategies and administrative relationships to explain every unique instance. Rather, the four dominant strategies, as developed by Shull, are used to delineate similarities and differences in working or task units, while the institutional/historical variable can be used to account for major deviations from the arrangements indicated by the model.

Finally, there is the question of the programmatic emphasis which Shull adopts. While such an emphasis in research may be dictated by extraneous factors, there is no reason to build this sort of an emphasis into the theory. Until field research gives one some reason to think otherwise, there is no theoretical barrier to the use of the matrix approach in explaining the organization of working units in the administrative system. In this case, it would seem advisable not to define or construct the organizational strategies exclusively in terms of project groups. To do so would be to fail to make use of all available tools to understand complex organizations.

The Propositions of the Matrix Approach

With the above changes, the propositions of the matrix approach can be restated. First, complex organizations are viewed in terms of an administrative and functional system and working units. The administrative system is considered to be that part of an organization that takes care of the routine administration of an organization. It would include the definition of long-range goals and policy, the organization's position to the extra-organizational environment, and similar matters handled by top-level administrators. It would also include functions generally referred to as staff functions, personnel, services, training, etc. The functional system is considered by Shull as part of the administrative system, but is here defined separately as that part of the organization that recruits and is composed of specialists in a particular discipline or function and is charged with supplying the expertise of its area to the organization. These are generally regarded as line or operating units, such as engineering, production, and sales in manufacturing organizations, or various departments - gynecology, surgery, obstetrics, etc. - in a medical organization. Working units are ad hoc or permanent groups of personnel charged with a specific task. Task forces and project groups are the obvious examples. Working units may be entirely within the administrative and functional system, or they may be more or less autonomous from that system.

Second, the organizational structure of the working units and their relationship to the administrative and functional system are dependent upon and vary in relation to three crucial variables: personnel

characteristics, particularly in terms of increasing personal specialization and increasing cosmopolitan identification; task characteristics, particularly in terms of programmed or unprogrammed (hueristic) decision processes and a similar or unique flow of tasks; and institutional and historical conditions, including the composition of the personnel system, the maturity of the organization, and unique organizational or professional norms.

Personal specialization refers to the internalization of working programs or techniques. The more personally specialized personnel have learned or internalized more, and more complex, working programs or techniques. Engineers are more specialized than technicians, and physicists more specialized than engineers. Cosmopolitan identification refers to the degree to which the expertise is independent of the organization, in terms of both content and norms or standards or performance. An engineer is more cosmopolitan than a technician, and a physician is more cosmopolitan than an engineer.

Decision processes are programmed when the solution to a problem or the technique to be used has been decided and is not left open to the specialist. A technician's work is programmed while an engineer's work is usually a mixture of programmed and unprogrammed, and a research chemist concentrates on unprogrammed work. The task-flow is similar and repetitive when the personnel are expected to deal with a large number of tasks of one or a very limited number of categories, and is novel and unique when the personnel are expected to deal with a series of different tasks requiring different skills and solution

programs. A technician's work is similar and repetitive while a physicist's work is novel and unique.

Third, the first two variables, personnel characteristics and task characteristics interact in relatively predictable ways. They can be combined as dimensions of a matrix to yield several patterns or strategies of working unit structure and administrative relationships. For present purposes, the polar positions on the task characteristics dimension can be combined with four positions on the personnel characteristics dimension to produce some eight combinations: skilled/provincial-repetitive/programmed; skilled/provincial-novel/hueristic; specialist/provincial-repetitive/programmed; specialist/provincial-novel/hueristic; professional/cosmopolitan-repetitive/programmed; professional/cosmopolitan-novel/hueristic; creative/cosmopolitan-repetitive/programmed; and creative/cosmopolitan-novel/hueristic. Figure 2.1 gives an illustration of this matrix.

The dimensions of the matrix are continua, and the positions identified are nodal, that is, a distribution along the continuum would find large bumps or nodes at the identified position. Thus, a substantial number of cases are assumed to cluster at or near the nodal positions identified. When nodal positions on the two continua are combined to produce patterns or strategies, these are considered nodal patterns.

The assumption of a tendency toward co-variance between the two variables causes certain nodal patterns to tend to predominate. That is, these patterns are more likely to appear than the others,

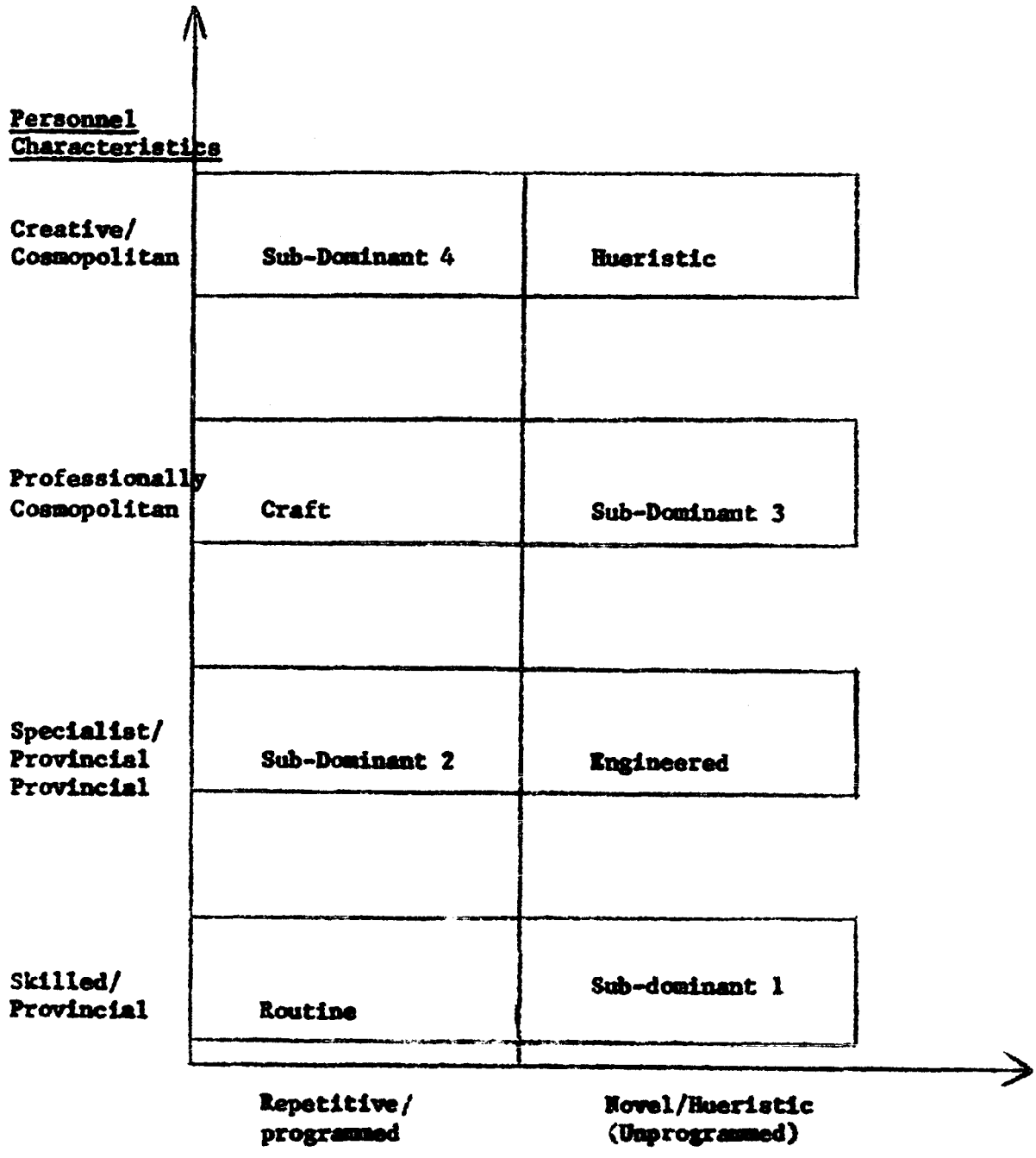

Figure 2.1 An eight-celled matrix with dominant and sub-dominant patterns.

which are labeled sub-dominant. The dominant patterns are those previously identified by Shull, i.e., the skilled/provincial-repetitive/programmed (routine) pattern, the specialist/provincial-novel/hueristic (engineered) pattern, the professional/cosmopolitan-repetitive/programmed (craft) pattern, and the professional/cosmopolitan-novel/hueristic (hueristic or diagnostic) pattern.[1]

The tendency toward co-variance is moderated by the third variable, particularly the composition of the personnel system and any unique organizational or professional norms. In such a case, the organization may not have the personnel requisite for the task at hand, or it may "under-employ" the skills of the personnel it has. Other factors, such as a lack of resources, or a shortage of trained personnel, might have the same effect and would be considered part of the third variable. The working unit itself may be organized along the lines of the rational design appropriate for the dominant position under the assumption of congruence or it may adapt to the sub-dominant reality.

The third variable may operate also to prevent a working unit that is in a dominant pattern of task complexity and personnel

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[1]The assumption of the tendency toward co-variance brings to light an additional problem. The model posits two task complexity positions and four personnel characteristics positions. If congruence or co-variance were the case there should be four task-complexity positions. Since the dimension is a continuum, such a realignment of the model is entirely possible. However, there seems to be no simple way to identify additional positions on this dimension that would contribute significant insights into organizational patterns and behavior. Introducing the two additional positions would greatly complicate the model by doubling the cells in the matrix without any additional explanatory power and is unwarranted.

characteristics from adopting the organizing strategy and administrative linkages that appear most appropriate to its particular pattern. Such action might be occasioned by unique organizational or professional norms, the maturity of the organization, or other factors. In any case, when a working unit deviates from the rational design that seems most appropriate to its position in the matrix, this may be taken as an indication of a shift in its position or as the impact of the third variable, or possibly both of these.

The Rational Designs for the Dominant Nodal Patterns

Shull describes in detail the working group organization designs and accompanying administrative linkages for each of the four dominant patterns or combinations. These descriptions are partially based on research findings in the literature on project and task groups, and they are stated in declaratory form. The example of the "Engineered" strategy has been given in full above. The descriptions of the other three strategies are included as Appendix A.

These descriptions are relatively static compared to the dynamic forces that shape complex organizations. The rapid development of technology and the rapid pace of personnel specialization are cliches even in the popular literature. However, the matrix approach itself is not necessarily a static conceptualization of organizations and the model presented here is particularly susceptible to a dynamic interpretation. Accordingly, it would seem helpful to rephrase the descriptions of the dominant strategies in terms of continua along

which the strategies are located. That is, the dependent variables would tend to change, proportionately or inversely, as the independent variables (principally the task complexity and personnel characteristics as modified by the third variable) change. In this interpretation, various working units could be ranked along the continua, or one working unit could move from one position to another along the continua as the task or the personnel changed, e.g., as a project moves through a life-cycle, as technology develops and changes, or as a total organization matures.

The descriptive propositions are grouped under the same headings Shull uses, and encompass most of the details that Shull pinpoints. The same form will be used to describe the variations in administrative linkages.

Organizing Strategies

Group Structure: As the pattern moves from the routine toward the hueristic, the group tends to become less homogeneous and the leadership tends to become less pre-eminent.

Group Process: As the pattern moves from the routine toward the hueristic, the group process tends to become less programmed and programs tend to be increasingly internalized by group members; coordination tends to become less dependent on external factors (program, leadership, etc.) and more dependent upon the group members, and correction mechanisms are increasingly internalized by group members.

Group Roles: As the pattern moves from the routine toward the hueristic, the group tends to become increasingly interdependent and the leadership role less differentiated.

Group Style: As the pattern moves from the routine toward the hueristic, the group style will tend to become less stressful, and quality and control specifications more subject to the group members.

Group Norms: As the pattern moves from the routine toward the hueristic, group norms will tend to become increasingly internalized, cosmopolitan, and oriented toward interaction and individual needs.

Administrative Relationships

Planning: As the pattern moves from the routine toward the hueristic, the administrative system tends to have less influence on the specification of processes, inputs and outputs.

Control: As the pattern moves from the routine toward the hueristic, the controls specified by the administrative system tend to become less specific, and in general control tends to become less a function of the administrative system and more a function of the group.

Rewards: As the pattern moves from the routine toward the hueristic, performance evaluation tends to be increasingly group centered and less individually centered and tends to become less a function of the administrative system and increasingly a function of the group; reinforcement of loyalty tends to become less directed

toward the aggregate organization and increasingly directed toward the group or profession.

Boundary Negotiations: As the pattern moves from the routine to the hueristic, resources tend to become increasingly a legitimate subject of negotiation and the working group tends to have greater influence over the specification of resources and the administrative system less influence.

The National Aeronautics and Space Administration

To develop further the ideas contained in the approach presented here, it seems useful to attempt to use the matrix approach to comprehend some part of a large, complex organization. The National Aeronautics and Space Administration appears to be a desirable subject for a number of reasons. It is a relatively new organization, particularly for one of its size. It has a radically new and challenging task, which seems to have encouraged flexibility in devising and applying new ways to do new things. It has extensive contacts with both the Department of Defense and with the aerospace industry which have a great deal of experience in project management. Project management represents an overt attempt to deal flexibly with the sort of organizational problems involved here and to consciously step out of the bureaucratic organizational mold. Consequently, many of the problems are overt and conscious, rather than being relegated to the workings of the "informal" system, and there is less of an attempt to defend the organizational arrangements in terms of bureaucratic management principles.

Additional reasons center on the role of organization and management in the national space effort. While there is a great deal of scientific research involved in the design, construction, and operation of space vehicles, there is just as much, if not more, utilization of existing technology. The scientific research can be and is farmed out to existing research centers, while the organization and integration of existing technology, along with that created for the space program, into the shape and form needed to carry out its mission is uniquely NASA's responsibility. The top management officials of NASA have emphasized the managerial challenge that the space program represents. The efforts of nearly half a million people had to be integrated to design, fabricate, test and assemble millions of parts in complex systems to perform to the highest possible standards of reliability. All this had to be accomplished on time and with all due attention to the total cost of the effort. The scientific accomplishments of the space program are real and readily apparent. The managerial accomplishments of that program, though generally only dimly perceived, are just as real and possibly even more remarkable.

Finally, the space program is, to all intents and purposes, completely open. Of course, certain technical information may be secret, but this is certainly minimal, and certain industrial information is guarded to protect corporations which must compete against each other, but generally this does not involve organizational relationships. The open character of the space program can be overemphasized. As with any governmental organization, NASA must be concerned

about the image it presents to the public, and it seeks in very subtle ways to protect that image. This can work in two ways. First, NASA is responsible to the general public and to the academic public. Aware of the organization's commitment to openness, NASA employees generally seem to take pride in cooperating with public requests for information as far as is possible and consistent with the intense pace of their own work. In addition, they generally appear accustomed to academic interest in their activities and are very cooperative in describing their working and organizational relationships.

On the other hand, there is a reluctance to air dirty linen in public, a reluctance to criticize colleagues, whether within the agency or outside it, a tendency to emphasize the positive, successful aspects and to de-emphasize the negative, unsuccessful areas. All of this is a natural, human tendency in any organization, and especially in an organization with a high degree of commitment. And it appears to be difficult to find a NASA employee who does not share a high degree of commitment to the space effort, to NASA, and to their own organizational unit. Dissatisfaction appears to run in the direction of a desire to do more, to build bigger and better vehicles, to explore all of space within our reach and to extend that reach as far as possible.

The openness of the space program is especially unique and important in relation to the significance of project management, for most other projects in the aerospace industry are under Department

of Defense management and security regulations. Thus, they are not nearly as open to public scrutiny and academic research as is the case with NASA.

The NASA Organization

The National Aeronautics and Space Administration was created partially out of the older National Advisory Committee on Aeronautics organization, and NASA has gone through repeated reorganization as the emphasis in the national space field has shifted. However, the major alignments were relatively stable from about 1963 through 1969, the period of greatest activity in the Apollo Program, which is the largest component of America's space effort.

NASA is headed by an Administrator, with a Deputy Administrator, an Associate Deputy Administrator and six Associate Administrators. Two of the Associate Administrators head staff arms; one of the Office of Organization and Management and the other oversees the Office of Policy and the Office of Program Plans and Analysis. The remaining four Associate Administrators are sometimes referred to as Program Associate Administrators, but this reference tends to be misleading and is used with decreasing frequency. These Associate Administrators head the Office of Manned Space Flight, which manages the manned space program, the Office of Space Science and Applications, which manages the unmanned space program, the Office of Tracking and Data Acquisition, which develops and operates the world-wide tracking networks for both the manned and unmanned programs, and the Office of Advanced Research and Technology, which is the research

arm of the organization. All of NASA's major field centers and most of the minor field installations are administratively located under these Associate Administrators.[1]

Due to the national commitment to land a man on the moon and return safely, the high cost and complexity of that effort, and the strong support of Congress, the Apollo Program is the focus of the space effort and the largest program within NASA. It has been in existence for more than seven years, which is a long time for a research and development program. The appropriations for Apollo have been the largest part of NASA's total appropriations. The Apollo Program's size, complexity, maturity and diversity make it an excellent subject for testing the matrix approach.

The various programs are located under the Associate Administrators also, and the Apollo Program, the Apollo Applications Program, and the Advanced Missions Program are located under the Office of Manned Space Flight. These programs are carried out through the three Manned Space Flight Field Centers , the George C. Marshall Space Flight Center, the Manned Spacecraft Center and the John F. Kennedy Spacecraft Center. The Marshall Space Flight Center (MSFC) at Huntsville, Alabama is charged with developing the launch vehicles for the manned space program. The Manned Spacecraft Center (MSC) at Houston, Texas is responsible for the development of spacecraft, the training of astronauts and the control of missions in progress.

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[1]See organization charts in Appendix B.

The Kennedy Space Center (KSC) at Cape Kennedy, Florida assembles, checks out, and launches the launch vehicles and spacecraft.

From the Washington Headquarters to the field centers, there are two lines of authority or direction, the general management direction from the Office of Manned Space Flight (OMSF) and the program direction from the Apollo Program Office within the Office of Manned Space Flight. Since Apollo is within OMSF and both lines of direction flow, at least formally, through the Director of the Center concerned, possible conflicts are avoided. However, within the field centers are program offices which are directly responsible for the accomplishment of all, or some part, of the Center's Program responsibility. In the case of MSFC, these offices were grouped under the Director of Industrial Operations (IO).[1] Both the Saturn 1-B Program Office and the Saturn V Program Office developed launch vehicles for the Apollo Program, while the Engine Program Office developed rocket engines for both programs. There is also an Apollo Applications office in IO. At MSC, the principal program office is the Apollo Spacecraft Program Office, but other Apollo Program responsibilities are handled by the Director of Flight Crew Operations for astronaut training and the Director of Flight Operations for mission planning and control as well as some

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[1]MSFC has gone through a reorganization since the research for this work was completed which entailed changing names of various offices and considerable realignment of other elements. For instance Industrial Operations is now referred to as Program Management. For this work, the older terminology, current from 1963 to 1968, is used to obviate obfuscation.

other elements of that center. At KSC there is an Apollo Program Office which serves as principal liaison office for the other Centers and Headquarters, but operating responsibility is in the hands of the Director of Launch Operations.

While formal lines run through the Center Directors, there are acknowledged direct communication links between the Headquarters Apollo Program Office and the Program elements in the field centers. To facilitate this communication the Program Offices are organized on what is sometimes referred to as the "mirror box" principle. The Apollo Program Office at Headquarters is organized into five "functional directorates", Program Control, Systems Engineering, Test, Reliability and Quality, and Flight Operations. Each program element at the field centers is organized into these five specialties as well as the operating responsibilities that they have.[1] Over the course of the Program this concept has been modified to some extent but remains essentially intact. At MSC, the Reliability and Quality Office has been elevated to a staff arm of the Center Director, and there is some indication of a tendency to combine the Reliability and Quality Assurance with the Test function, but on the whole these functional specialties survive.

The program offices at MSFC and MSC manage contracts for the development of the hardware required for the Apollo Program.[2] These offices are responsible for monitoring the contractor's prog-

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[1]The chart from the Saturn V Program Procedures Manual in Appendix B demonstrates this relationship quite well.

[2]The Apollo Program Office at KSC does not have primary responsibility for hardware research and development. Though it has a somewhat similar organizational position, it is excluded from further consideration.

ress on their hardware, for all technical direction to the contractor that may be necessary, for decisions on engineering change proposals, and in general for seeing that the hardware is produced within the relevant technical, cost and schedule constraints. In doing this, the program offices receive technical assistance from the engineering division of their Center. At MSFC this organization is the Directorate of Research and Development Operations. It is organized into a number of laboratories, and the labs into sections. Each lab or sometimes the section has a designated project engineer for each launch vehicle stage project office that it supports, including the Instrument Unit and the Ground Support Equipment. At MSC, the engineering organization is the Directorate of Engineering and Development, which is organized into divisions under two Assistant Directors, one for Chemical and Mechanical Systems, and one for Electronic Systems. Each division supplies engineers to act as subsystem managers for the spacecraft subsystems which fall in their area of responsibility. In addition, some divisions also assign project engineers. The subsystem managers perform the program office responsibility for their particular subsystem of the spacecraft. They monitor contract work progress, send directions to the contractor through the program office, make initial and some final decisions on engineering changes within their area of responsibility and are the first-line integrators of technical, schedule and cost restraints.

At MSFC the subsystem engineers are located in the Program Office and this is one of the principal differences in the organiza-

tion of the two Centers. Another principal difference is that the MSFC Program organization is divided into project offices with project managers for each stage of the vehicle and for the group support equipment, while the Apollo Spacecraft Program Office (ASPO) at MSC is not nearly so neatly divided along hardware lines. If the matrix approach to organization theory is to be useful at all, it should be able to give some insight into the reasons for these differences. In addition, it should give some indication of how these organizations will react to certain kinds of stress, especially that originating in a radical shift in the nature of the task or lack of required personnel.

The Collection of Data

To test the matrix approach it is necessary to understand the task of the organization, the type of personnel it has, and the organization of the working groups and their relation to the total organization. A substantial amount of this information about the project management groups at MSFC and MSC was gathered in a series of interviews with NASA project managers and associated personnel. These interviews were conducted at the Centers, in the respondents' offices, generally, and according to an open-ended, relatively unstructured interview schedule.

The interviews were conducted as part of an inter-disciplinary research project on project management which included researchers from aerospace engineering, business administration, and sociology.

as well as students of political science and public administration. The interview schedule was prepared in cooperation with the participants in the project and their comments and suggestions added to the quality of the instrument. The schedule was pre-tested on an engineer employed by a company working on a project in some ways analogous to the NASA project. This test demonstrated that the schedule was rather long, but rather than arbitrarily eliminate questions, the schedule was amended as the interviewing progressed. This procedure made it possible to eliminate those questions that elicited little response from NASA personnel.

The personnel to be interviewed were selected on the basis of the focus on hardware research and development project managers. Since these people were quite busy with their on-going work, it was not possible to interview every project manager on the list, but every effort was made to contact as many as possible. A contact was established at each Center through NASA Headquarters. The Center contacts arranged the interview appointments from the lists submitted to them. There were no indications of any screening effort on the part of NASA, but the contacts were most helpful in suggesting a number of additional personnel to interview and in arranging a few background briefings on the organization.

In addition, a number of NASA Headquarters in Washington, D.C. personnel were interviewed to obtain the Headquarters perspective and to collect information about the relationships between the Apollo Program and the total NASA organization. The

Headquarters interviews were arranged through the Headquarters NASA contact generally, though a few were arranged directly. Finally three members of the House of Representatives Committee on Science and Astonautics were interviewed as well as the former Administrator of NASA, Mr. James E. Webb. These interviews were conducted to obtain high-level perceptions of the space program, Apollo, and the role of project management in that effort. The full list of personnel interviewed, by position, is included in Appendix C.

The Headquarters and other interviews entailed considerable revision of the basic interview schedule. Again this was done in cooperation with the members of the interdisciplinary research project. The chief revisions tended to request descriptions of the respondents' position and responsibilities and their perceptions of the project manager's position and problems. The questions put to the Congressmen and to Mr. Webb were, of course, considerably different. All the basic interview schedules are included in Appendix C also.

All of the respondents were aware of the fact that the research was being conducted under NASA sponsorship, and most were quite interested in the purpose of the study and its possible results. They were given a very vague, general description of the purpose of the study and were asked to give their permission for the recording of the interview, with the assurance that the information was for the use of the interdisciplinary research project

members only. Almost all the respondents agreed to recording, though a few betrayed some anxiety about it.[1] Much more common was the reaction, "Well, I really shouldn't say this on the record, so to speak, but.....".

The interviews were transcribed, and two copies of each respondent's interview were mailed to him, the second copy to be returned if any corrections were necessary. About one-third of the respondents returned a corrected copy of the interview transcript. These varied in the number and depth of the corrections, but generally they were a matter of grammar, punctuation, spelling, and clarifying terms and other elements of jargon. Very few of the corrections changed the import of the responses, generally by striking a few words, and most of these were not on points that bear directly on the subject of this study. When quotations from these interviews are cited, they incorporate any corrections unless otherwise indicated.

In addition to the principal data used in this study, a number of interviews conducted by other members of the interdisciplinary research team are available to shed additional light on the subject. Most of the interview schedules for these interviews were constructed in cooperation with the members of the research project, and some incorporate revised versions of some of the questions in the instruments designed for the present study. Generally, they

[1]In addition, there were a small number of failures of the recording equipment. As much as possible, unrecorded interviews were reconstructed from the participants' notes.

were less structured and more open-ended, as well as focused on a slightly different aspect of the subject, but, the transcriptions are cited where the information is pertinent and useful. These interviews with a few additional project managers, a large number of subsystem managers, project engineers and contractor project managers and other contractor personnel in similar positions, give differing perspectives on the subject of this study. These perceptions of the NASA project management group serve as a check on the project managers' perceptions as well as give additional insights.

Propositions to Be Tested

Unfortunately, the available data was not sufficient to test all of the propositions of the matrix approach to the explanation of organizations. This is not surprising since many of the propositions of a theoretical model usually are not testable. The method of data collection utilized did not yield data to test every proposition that may be subject to empirical scrutiny, therefore, it is necessary to indicate those that are examined in this work.

The first step is to compare the internal organization of the project management groups at MSFC and MSC to the descriptions produced by the model and to the propositions on working group organization formulated from that model. The basic proposition to be tested here is that the NASA project management groups are

described by the engineered strategy and will tend to be located at that point on the continuum in regard to the statements on organizing strategies. This is the subject of Section Three.

Section Four is an application of the same test to the description of the administrative relationships of the project management groups. In the course of both these sections, certain differences or discrepancies are identified. Differences between MSFC and MSC have already been pointed out. Section Five is an attempt to relate these differences between MSFC and MSC to differences in their personnel-task characteristics. In addition, it constitutes an attempt to relate the deviations from the engineered strategy to deviations of the working groups from the nodal pattern of a combination of specialist/provincial personnel doing novel/unique and unprogrammed work.

As a project goes on, there are certain expected and unexpected changes in the task confronting the project group. These take the form of emergencies, crises and anomalies for the unexpected, and a life cycle pattern for the expected. When this happens the matrix model suggests that working patterns of the project group will change in some way in reaction. The propositions here are that as the group is confronted with emergencies or crises, it will react by moving toward a more hueristic pattern and that as a project matures it tends to become more routinized and the working patterns move toward the routine strategy. These propositions are tested in Section Six.

Section Seven examines some special considerations of the application of the matrix approach to project management. These center on the relationships between the project management group and the engineering support organization. Section Eight presents the conclusions derived from this work and suggests areas for further theoretical and empirical work.